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ABSTRACT

The study reported here was conducted in an effort to obtain data for comparing the combined owning and operating costs of two different types of air-conditioning systems in two elementary schools. Both schools were built during 1969-70 in the same geographical area along the southeast coast of Florida and are also served by the same electric utility company. They have been exposed to the same seasonal weather changes, building conditions, and economic impact. Since these schools are also similar in educational requirements and architectural planning, although completely dissimilar in air-conditioning or mechanical design concepts, a basis was established for a realistic, meaningful, and valid comparison. To carry out the study (1) energy consumption of equipment was metered, (2) replacement costs because of differences in longevity of equipment were adjusted, (3) first costs because of differences in design and owner requirements were adjusted, (4) "money costs" based on available funding options over an extended period of time were considered, and (5) maintenance costs were applied to operating costs. Study results show that it is more economical to own and operate the roof-mounted, multizoned, unitary type air-conditioning system than to own and operate the central, chilled water, terminal heat/reheat, type. (Author)

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the evaluation of unitary & central type air-conditioning systems

in selected florida schools

prepared for the
Department of Education
State of Florida
Tallahassee, Florida
Floyd T. Christian, Commissioner

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November 6, 1972

This public document was promulgated at an annual cost of $5372.12 or $3.58 per copy to inform Florida school district board members, administrators and others of cost analysis data pertaining to selected air-conditioning systems.

EA 004 973

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PREFACE

This study has been prepared for the Department of Education, State of Florida, Floyd T. Christian, Commissioner.

The author assumes full responsibility for the identification and selection of all material contained herein, including reproductions of metering charts and utility billings, theoretical calculations based on known data, tables, analyses, supportive data, and final conclusions.

The effort and time required to produce this document will have been well spent if but a single facility results therefrom that is environmentally useful and worthwhile.

ACKNOWLEDGMENTS

Sincere thanks and appreciation are gratefully extended to the individuals and organizations listed for their willing cooperation and help in gathering data contained herein. Without their valuable contributions and assistance, completion of this study would not have been possible.

DISTRICT SCHOOL BOARD OF PALM BEACH COUNTY, FLORIDA, for permitting the use of Eisenhower Elementary School; MR. ROBERT W. FULLER, Architect, Department of School Plant Planning; and MR. RALPH BROWN, Director, Department of Maintenance and Operations, for furnishing maintenance history and costs, and other related data.

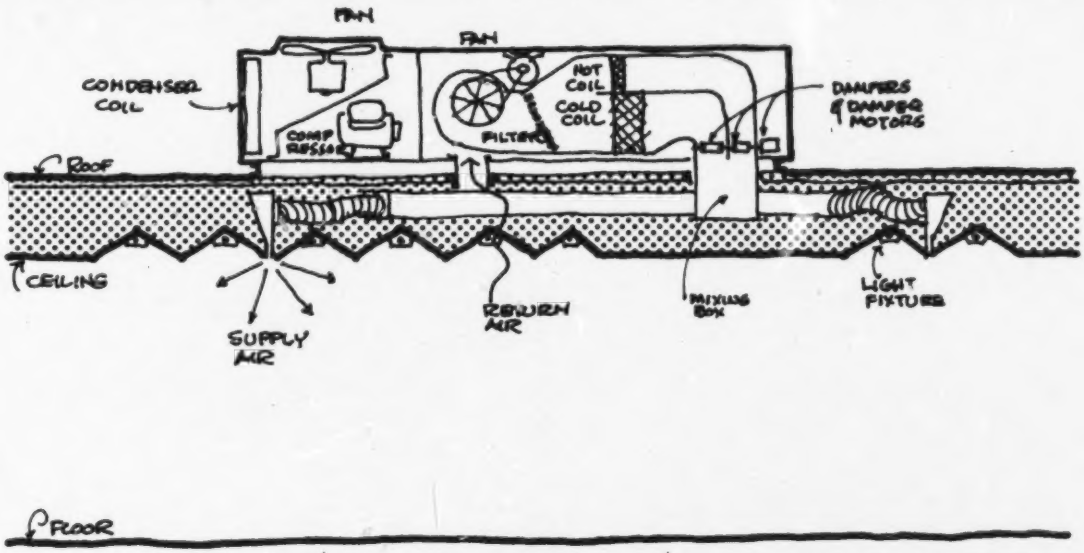
DISTRICT SCHOOL BOARD OF DADE COUNTY, FLORIDA, for permitting the use of Bel-Aire Elementary School; MR. ARISTIDES MARTINEZ, P.E., of the firm of Ferendino, Grafton, Spillis and Candella; MR. F. H. KLINE, Assistant Superintendent, Physical Plant; and MR. E. C. KENNY, Supervisor, Utilities Utilization, for furnishing data and information vital to this study.

FLORIDA POWER AND LIGHT COMPANY for providing electrical watt-hour and demand meters; MR. R. V. EASTHAM, Florida Power and Light (West Palm Beach Office) for coordinating meter placement and operation at Eisenhower Elementary School; and MR. T. H. ANDERSON, Florida Power and Light (Naranja Office) for coordinating meter placement and operation at Bel-Aire Elementary School.

NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION, Miami International Airport Station and West Palm Beach International Airport Station for providing records of actual outdoor temperatures and humidities.

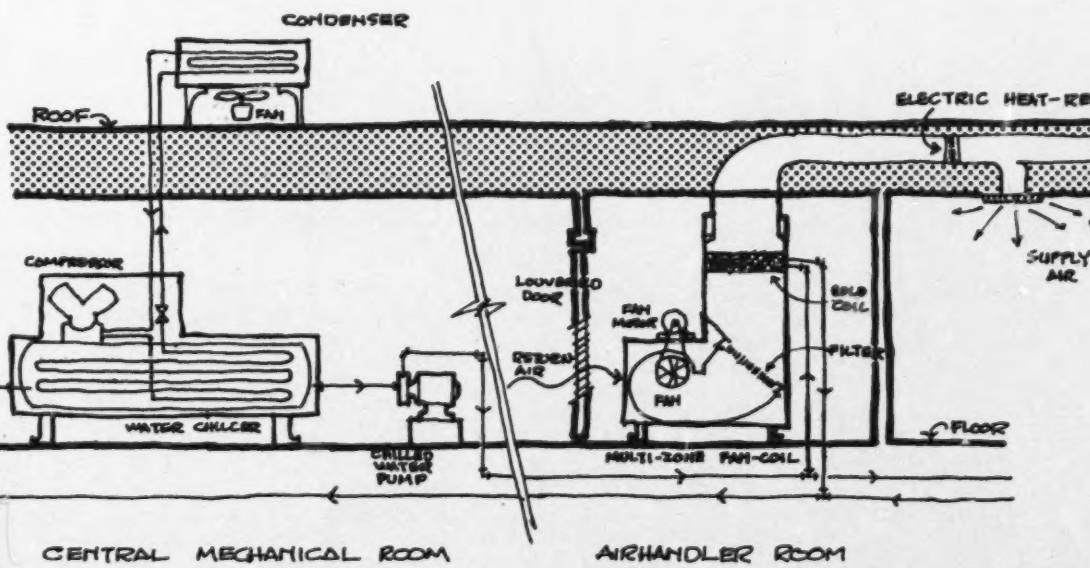
PRINCIPALS, TEACHERS, STAFF AND STUDENTS at both schools for their patience, understanding and indulgence during periods of inconvenience while temperatures and humidities were being recorded.

BUREAU OF SCHOOL FACILITIES, Division of Elementary and Secondary Education, Department of Education, State of Florida, for furnishing valuable information and records throughout the entire period of assembling data for this study.



ROOF MOUNTED MULTI-ZONE UNITARY TYPE AIR CONDITIONING SYSTEM

PLATE ONE



CHILLED WATER TYPE AIR CONDITIONING SYSTEM

PLATE TWO

PURPOSE OF STUDY

This study has been conducted in an effort to obtain data for comparing the combined owning and operating costs of two entirely different types of air-conditioning systems. The two schools wherein these systems have been installed, and are fully operational, are the Dwight D. Eisenhower Elementary School in Palm Beach County and the Bel-Aire Elementary School in Dade County, Florida.

Both Schools were build during 1969-70 in the same geographical area along the southeast coast of Florida, and are also served by the same electric utility company. Therefore, this likeness of consequences has indeed exposed them to the same seasonal weather changes, building conditions, and economic impact. Finally, since these schools are markedly similar in educational requirements and architectural planning, but completely dissimilar in air-conditioning, or mechanical design concepts, the basis for a realistic, meaningful and valid comparison is firmly established.

DESCRIPTION OF SUBJECT SCHOOLS

The Eisenhower Elementary School (one of eleven projects in Program 3, Florida SCHOOLHOUSE SYSTEMS PROJECT [SSP][1]) contains approximately 44,190 gross square feet of space and is air-conditioned and heated by a roof mounted multi-zone unitary type system.[2] The system consists of five self-contained packaged rooftop units which utilize hot refrigerant gas to supply reheat.[3] Facilities include an equivalent of twenty primary and elementary classes in an open space design, a cafetorium with satellite serving kitchen, central materials center, administrative suite, multi-purpose area plus necessary service, storage and toilet areas.

The Bel-Aire Elementary School contains approximately 39,885 gross square feet of space and is air-conditioned by a chilled water terminal reheat type air-conditioning system.[4] This system consists of two packaged water chillers, two air cooled condensers, six standard multi-zone air handling units, and two pumps. The chillers and pumps are located in a central mechanical room; the condensers are mounted on the roof; the air handlers are located in four air handler equipment rooms. Heat and reheat are accomplished by duct mounted terminal electric strip heaters. Facilities include the equivalent of twenty primary and elementary classes in an open space design plus two kindergarten rooms, a food preparation-type kitchen with auxiliary food serving area, decentralized library facilities, administrative suite, multi-purpose area plus necessary service, storage and toilet areas.

Both schools fulfill the educational requirements that prevailed in their respective districts at time of construction; the Eisenhower School based upon a design capacity of 525 pupils and the Bel-Aire School based upon a design capacity of 630 pupils.

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[1] Section in the Bureau of School Facilities, Division of Elementary and Secondary Education, Department of Education, State of Florida, engaged in offering consulting services in fast-track construction programming and systems building process as part of the Department's interest in building better schools more economically and more rapidly.

[2] The roof mounted multi-zone unitary type air-conditioning unit basically consists of a self contained equipment package on the roof containing a condenser, compressor(s), expansion valve(s), an expansion coil, necessary fans and fan motors, multi-zone dampers and damper motors, and an electric heating section.

[3] A sophisticated air-conditioning system ultimately chills the air to a set temperature and adjusts the humidity (moisture content of the air) to a fixed percentage. Both temperature and humidity must be within the comfort range when the conditioned air is delivered to the occupied spaces. Moisture is removed by passing the air over a very cold coil, but the air is then too cool for comfort. The "too cool" air is passed over another coil and heated to an acceptable temperature. The last operation is referred to as "reheat". In the rooftop unitary system, reheat does not require additional electric energy but is obtained from the hot refrigerant gas, that otherwise would reject its heat to the atmosphere during the refrigeration cycle.

[4] A chilled water type air-conditioning system, often referred to as a central system, consists of chiller(s)-(refrigeration devices to chill water), cooling tower or condenser(s)-(to reject heat), and pumps-(to circulate the chilled water). Except for the cooling tower or condenser(s), located outdoors, these equipment items are generally located in a relatively centralized mechanical equipment room. Remotely located from the chiller but connected by a piping system, are fan-coil air handlers, some (or all) of which may have multi-zone capability. Chilled water is circulated to the air handlers through the piping system and back to the chiller. The air from the conditioned space passes over the cold coil in the fan-coil air handler and back into the conditioned space. Room heat is transferred to the water in the fan-coil. Heat in the water is transferred to the refrigerant at the chiller and rejected at the cooling tower or condenser. In this system the cooled air passes through an electric resistance heater (heat/reheat) coil before returning to the conditioned space.

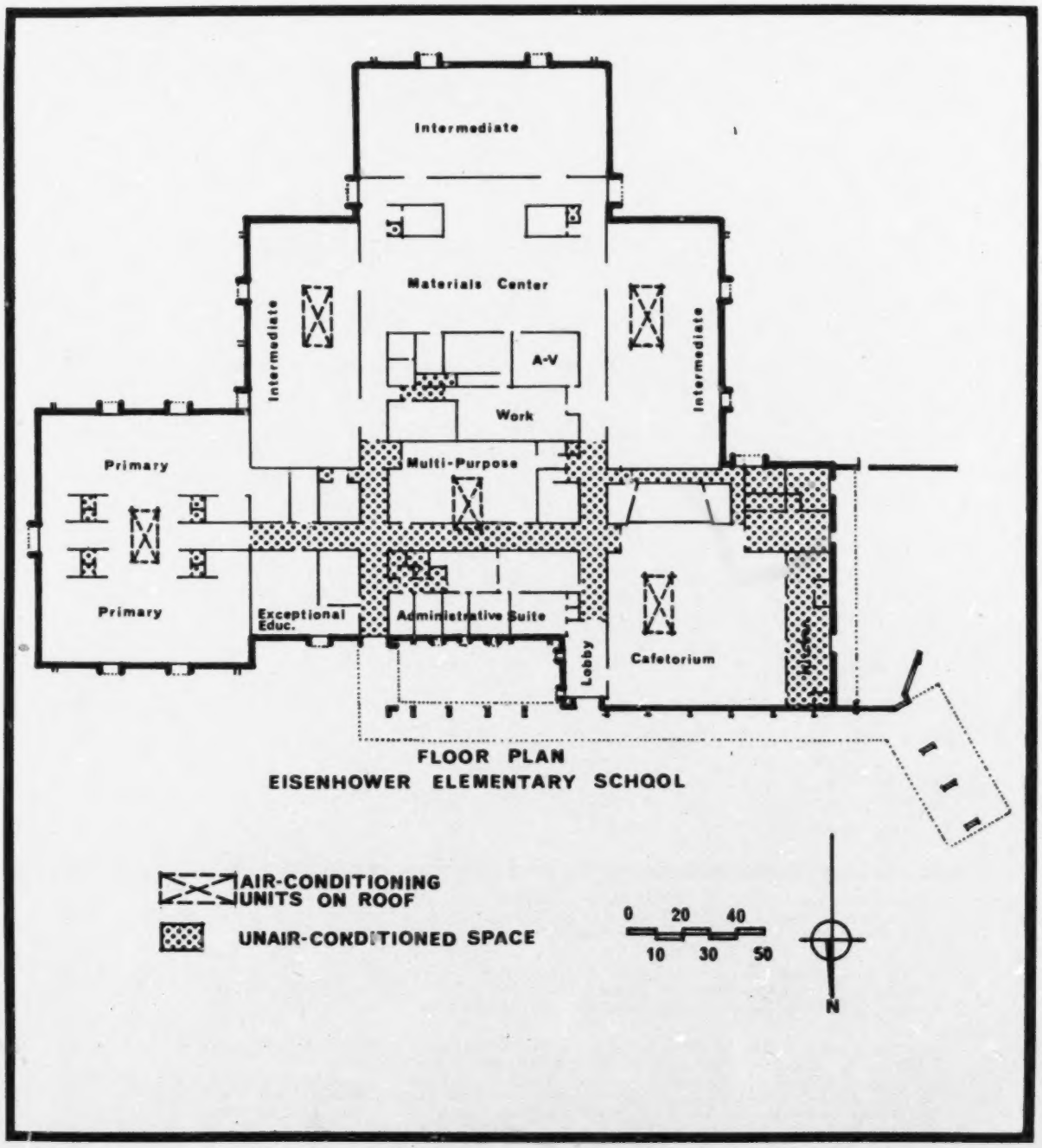
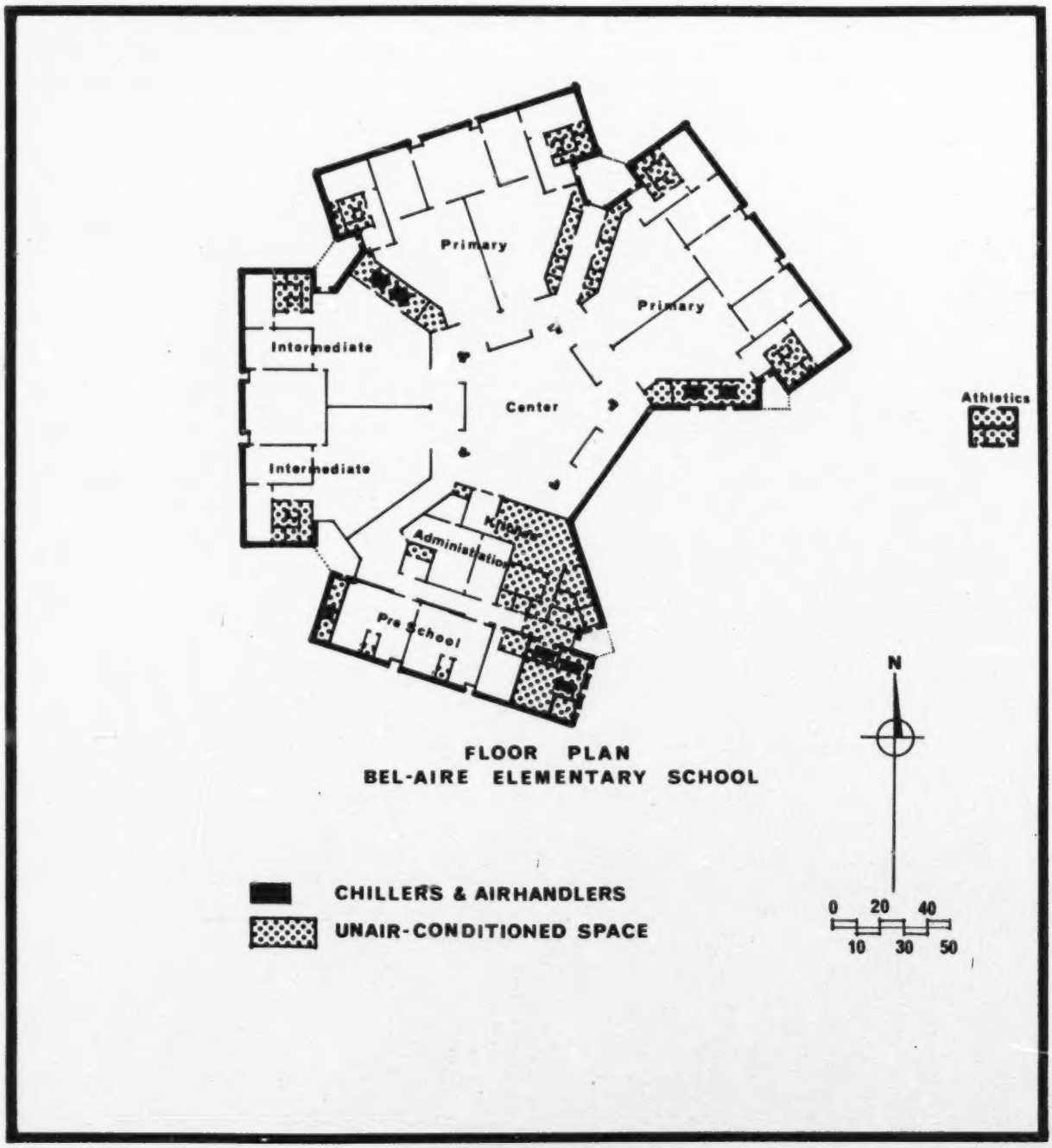

Intermediate
Materials Center
Intermediate
Intermediate
A-V
Work
Primary
Multi-Purpose
Primary
Exceptional Educ.
Administrative Suite
Lobby
Cafetorium
FLOOR PLAN
EISENHOWER ELEMENTARY SCHOOL
AIR-CONDITIONING UNITS ON ROOF
UNAIR-CONDITIONED SPACE
0 20 40
10 30 50
N

PLATE THREE



FLOOR PLAN
BEL-AIRE ELEMENTARY SCHOOL

PLATE FOUR

APPROACH AND PROCEDURES

This study was not concerned with the wisdom of design decisions made by others relating to quantity or quality of the mechanical systems in these two test schools, nor the reasons therefore. However, significant differences were noted for which appropriate adjustments have been made to support the methods and procedures used, including analysis and calculations based upon metering the other data, and to justify conclusions reached.

The procedures used in this study include (1) metering energy consumption of equipment, (2) adjustment of replacement costs due to differences in longevity of equipment, (3) adjustment of first costs due to differences in design and owner requirements, (4) consideration of "money costs" based upon available funding options over an extended period of time, and (5) application of maintenance costs to operating costs.

METERING TECHNIQUES

Metering, or measuring, electrical energy was the most important single step in gathering data for this study and was maintained on an uninterrupted basis for a complete school year from Septemeber, 1971 to June, 1972.

The procedure for metering the schools and their respective air-conditioning systems, and also the reheat component at the Bel-Aire School, consisted of the following:

1. Measurement of total kilowatts of electrical energy consumed each month at both schools for the full metering period. See Appendix for example.

2. Measurement of kilowatts of electrical energy consumed each month by the air-conditioning equipment only at both schools for the full metering period. See Appendix for example.

3. Measurement of kilowatts of electrical energy consumed by the electric heat/reheat resistance coils at Bel-Aire Elementary for the months of April, 1972 and May 1972.[5] See Appendix for example.

4. Measurement of the relative humidity, indoors and outdoors, See Appendix for example.

ADJUSTMENTS DUE TO EQUIPMENT LIFE

The following table lists generally accepted, standard longevities for major components of air-conditioning systems as established by industry[6] and the American Society of Heating, Refrigeration, and Air-Conditioning Engineers:

Reciprocating Chiller	20 years
Air Cooled Condenser	20 years
Pumps (Chilled Water)	20 years
Air Handling Units	20 years
Controls	15 years
Ductwork and Air Distribution	20 years
Piping and Insulation	20 years
Roof-top Self-Contained Units	10 years

[5]The average yearly heat/reheat electric power consumption has been set by the author at 25% of the total air-conditioning power requirement by a combination of the recorded heat/reheat electric power consumed during April, 1972 and May, 1972 and estimated requirements for cooler, less humid months.

[6]The Trane Company, LaCrosse, Wisconsin.

These longevities are based upon full year operation and therefore a school system which utilizes its facilities only for the more normal 9-month period will automatically extend the expected longevity of its equipment. However, even with a 9-month utilization, school facilities along the southeast regions of Florida tax air-conditioning equipment to their fullest limits because of the long operating cycle, plus the damaging effects of salt laden ocean air carried ashore by prevailing winds.

Since roof-top, self contained units have an assumed life of 10 years,[7] as compared to the accepted 20 years for chillers, condensers, pumps and air handlers, the latter of which are components of a central type system, this study makes appropriate upward adjustments in the future cost of early replacement of the 10-year life equipment. This cost is estimated to be 50% greater than the initial cost, plus an additional $5,000 for disconnecting and removing existing equipment and placement and connecting of new equipment, or $68,750.00.

ADJUSTMENTS DUE TO DESIGN AND OWNER REQUIREMENTS

The subcontract cost of the air-conditioning system for the Eisenhower Elementary School was $78,870, but this cost did not include kitchen ventilation which was provided under another contract for $4,500. Thus the total HVAC cost for the Eisenhower School was $83,370. The total HVAC[8] cost for the Bel-Aire School, including kitchen ventilation, was $187,000.

Various adjustments that must be made to the above figures, to effect a more equitable basis for comparison, are listed in the Tabulation of Initial and Adjusted Costs on page 8 and are explained as follows:

1. Add $10,000 to the Eisenhower Elementary School HVAC cost to compensate for more expensive type ductwork required by Board policy for the Bel-Aire Elementary School.[9]

2. Add $16,670 to the Bel-Aire Elementary School HVAC cost to cover the cost of providing necessary enclosed space to accommodate mechanical equipment.[10]

3. Subtract $4,500 from the Eisenhower Elementary School HVAC cost and $10,500 from the Bel-Aire Elementary School HVAC cost to delete the kitchen ventilating provisions from both projects.[11]

The Adjusted Air-Conditioning System Contract Costs thus become $88,870 for Eisenhower and $193,170 for Bel-Aire.

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[7] The more recent, improved equipment of the type installed at the Eisenhower Elementary School has only been in use approximately six years, and has not yet had the benefit of long-term field testing.

[8] HVAC as used here is an abbreviation for Heating, Ventilating and Air-Conditioning System.

[9] This figure was obtained from Hill York Sales Corporation, Miami, Florida, (installing air-conditioning contractor for the Eisenhower Elementary School) to substitute metal ductwork with wrap-around insulation, as required by School Board of Dade County policy, and specified for the Bel-Aire Elementary School, in lieu of fiberglass ductwork furnished for the Eisenhower School.

[10] Although this space is part of the total building area, it is space that is required solely because of the type of air-conditioning system employed. Thus the cost (1,667 sq.ft. @ $10.00/sq.ft.) is assignable to the overall mechanical cost and not to general construction cost.

[11] These costs are deleted from consideration as they relate to provisions that are (1) not comparable in quality or quantity, and (2) not essential parts of the HVAC installations.

TABLE ONE

TABULATION OF INITIAL AND ADJUSTED COSTS

EISENHOWER SCHOOL		BEL-AIRE SCHOOL	
Roof top Multi-zone Units	$42,500.00	Multi-zone Air Handling Units	$ 7,950.00
Ductwork, Air Distribution, Labor, Overhead and Profit	36,370.00	Chillers and Air Cooled Condensers	13,000.00
Subtotal	$78,870.00	Pumps	650.00
Ventilation Contract	4,500.00	Expansion Tank	100.00
INITIAL COST	$83,370.00*	Isolators	425.00
		Controls	9,174.00
			$ 31,299.00
Metal ductwork equivalent amount	+10,000.00	Sheet metal, piping	$ 49,000.00
Kitchen Ventilation System	−4,500.00	Insulation	23,700.00
		Air Distribution, Fans, Electric heaters	12,035.00
		Hood Filters	450.00
		Test and Balance	1,500.00
			$ 86,685.00
		Labor, Overhead and Profit	$ 69,016.00
ADJUSTED COST	$88,870.00	INITIAL COST	$187,000.00*
		Kitchen Ventilation System	−10,500.00
			$176,500.00
		Mechanical Equipment Rooms equvalent amount	+ 16,670.00
		ADJUSTED COST	$193,170.00

*Construction Contract Amount

TABLE TWO

COMPUTATION OF UNIT COSTS

SCHOOL NAME	BEL-AIRE	EISENHOWER	Percent Difference
Location (county school district)	Dade	Palm Beach	
School Opened for Use	Sept., 1970	Sept., 1970	
Type Air-Conditioning System	Chilled Water	Unitary, Roof Top	
Area, Gross Square Feet (AIA Method)	39,885	44,190	11%
Area, Net Conditioned Square Feet	35,035	41,090	17%
Bldg. Cubic Volume, Conditioned Space	488,211	540,398	11%
Students, Design	630	525	20%
Students, Average Daily Attendance (A.D.A.)*	494	643**	30%
Cost, Total Construction	$926,854.00	$874,544.00	6%
Cost, Per Square Foot, Total Construction	$ 23.24	$ 19.79	18%
Cost, Per Square Foot, Conditioned Space	$ 26.46	$ 21.28	24%
Cost,Per Bldg. Cubic Foot, Conditioned Space	$ 1.90	$ 1.62	17%
HVAC Contract	$187,000.00	$ 83,370.00	124%
HVAC Cost Per Square Foot Conditioned Space	$ 5.34	$ 2.03	163%
HVAC Cost Per Student, Design	$ 296.83	$ 158.80	87%
HVAC Cost Per Student, A.D.A	$ 378.54	$ 129.66	192%
HVAC Cost Per Bldg. Cu-Ft. Conditioned Space	$ 0.38	$ 0.15	153%
Adjusted HVAC Cost	$193,170.00	$ 88,870.00	117%
Adjusted Cost Per Sq.Ft. Conditioned Space	$ 5.51	$ 2.16	155%
Adjusted Cost Per Student, Design	$ 306.62	$ 169.28	81%
Adjusted Cost Per Student, A.D.A.	$ 391.03	$ 138.21	183%
Adjusted Cost Per Bldg. Cu-Ft. Conditioned Space	$ 0.40	$ 0.16	150%
Tons of Refrigeration (Compressor)	122.80	134.00	9%
Tons of Refrig. Per Sq.Ft. Conditioned Space	.00350	.00326	7%
Electric Cost, Total ***	$ 14,370.22	$ 10,195.41	41%
Electric Cost, HVAC ****	$ 9,774.50	$ 7,222.84	35%
Electric Cost, HVAC Per Sq.Ft. Conditioned Space	$ 0.28	$ 0.18	56%
Electric Cost, HVAC, Per Student, Design	$ 15.52	$ 13.76	13%
Electric Cost, HVAC, Per Student, A.D.A.	$ 19.79	$ 11.23	76%
Maintenance Cost, HVAC *****	$ 489.98	$ 1,277.48	161%
Maintenance Cost HVAC Per Sq. Ft. Cond. Space	$ 0.0140	$ 0.0311	122%
Maintenance Cost, HVAC Per Student, Design	$ 0.78	$ 2.43	212%
Maintenance Cost, HVAC Per Student, A.D.A./Hr. Used Per Day	$ 0.17	$ 0.20	18%

* Bureau of District Finance and Business Management, Division of Elementary and Secondary Education, Department of Education, State of Florida.

** Eisenhower was on double session; 400 A.D.A. for the morning session and 243 A.D.A. for the afternoon session. Morning session was from 7 A.M. 'til noon and the afternoon session was from noon 'til 5 P.M.

*** The total electric cost is the sum of the billings for the period September, 1971 to June, 1972. See page 10

**** The total HVAC electric cost is the sum of the calculated HVAC power costs. See page 10

***** These costs are for the period September 1, 1971 to June 1, 1972, and were furnished by the school district personnel. See Comments re: Maintenance Costs, page 11 and tabulations on pages 20 and 21.

TABLE THREE

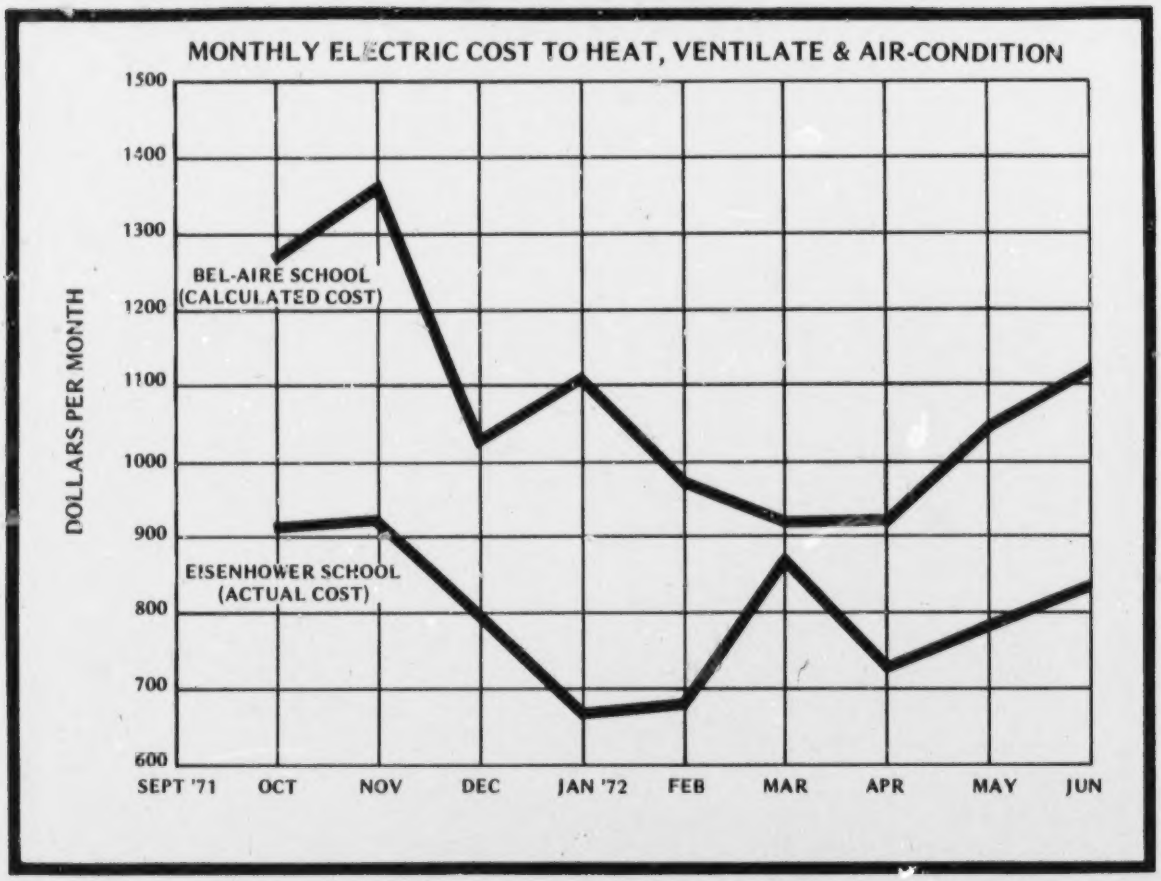

TABLE FOUR

TABULATION OF MONTHLY HVAC ELECTRIC POWER COSTS

BILLING FOR MONTH OF	ACTUAL A/C POWER COST	ACTUAL HEAT/REHEAT POWER COST	CALCULATED (25% OF A/C POWER COST) HEAT/REHEAT POWER COST	TOTAL CALCULATED HVAC POWER COST	TOTAL ACTUAL HVAC POWER COST	TOTAL ACTUAL HVAC POWER COST
SEPTEMBER '71	1,017.67		254.42	1,272.09		917.01
OCTOBER	1,092.65		273.16	1,365.81		925.80
NOVEMBER	824.91		206.23	1,031.14		798.98
DECEMBER	884.67		221.17	1,105.84		667.73
JANUARY '72	781.07		195.27	976.34		681.64
FEBRUARY	740.15		185.04	925.19		873.52
MARCH	740.97		185.24	926.21		729.33
APRIL	838.12	227.70	209.53	1,046.60	1,064.98	789.09
MAY	900.22	264.15	225.06	1,125.28	1,164.37	839.74
				BEL-AIRE SCHOOL		EISENHOWER SCHOOL
			TOTAL	$9,774.50		$7,222.84

FUNDING AND CONSIDERATIONS OF "MONEY COSTS"

Funds for construction of public schools in Florida School Districts are derived from two principal sources. These sources are current expenditure monies and bond monies. The former are tax monies and require no interest on the amounts used. They have included State Capital Outlay and Debt Service Funds, State Educational Improvement Expense Funds, Exceptional Education Funds, Federal Funds, and County Current and District Funds, sometimes referred to as "Pay-As-You-Go" Funds. Bond funds must be paid back with interest and for the purposes of this study the interest rate is calculated at six percent (6%).[12] The bond maturity is calculated over 20 years. Bond sources in Florida include State Board of Education (SBE) Bond Funds, Special Law Funds, District Number One Bond Funds and Vocational, Technical Center Capital Outlay Funds derived from Higher Education Bond Funds.

Capital outlay expenditures in the past have been funded almost equally from current expenses (53%) and from bonds (47%). Therefore, this study considers both methods of funding in comparing and projecting the cost of owning and operating these two subject air-conditioning systems.

APPLICATION OF MAINTENANCE COSTS TO OPERATING COSTS

Maintenance is of prime importance in increasing the useful life of air-conidtioning systems and also in holding equipment "down time" to a minimum. Assigning a cost for this service, however, is very difficult and sometimes misleading, as preventive maintenance and corrective maintenance must both be taken into account. In many school systems the work is often fragmented and hard to separate and identify.

Although both the Dade and Palm Beach District School Systems have maintenance sections, or divisions, and provide a wide variety of services in this respect, the costs of these services given by the respective staffs during this metering, or data-gathering period, were considerably below any reasonable projected values.

Therefore, because of this, and also because of a great divergence in maintenance costs as reflected in quotations submitted by service contractors, maintenance costs used for the 20-year cycle projections in this study have been those obtained from the Bureau of School Facilities.[13]

Another factor to consider is the cost of custodial care and maintenance of the additional building space required for the mechanical equipment rooms in the Bel-Aire Elementary School. This cost cannot be overlooked and for the purpose of this study is computed at the rate of 13¢ per square foot per year.[14]

The air-conditioning system at the Eisenhower Elementary School consists of roof-top, self-contained packaged units, thus requiring no additional building space to house the equipment. However, air-conditioning service contractors advise that a small factor is always added to their costs for servicing roof-mounted units, and this same factor is included in the maintenance costs used in this study.

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[12]Total average yearly interest payments are shown as "Money Costs" in tabulations on pages 16, 17 and 18.

[13]Energy Systems Consultants, "THE EVALUATIONS OF SELECTED AIR-CONDITIONING SYSTEMS FOR PUBLIC SCHOOLS - 9 months? or 12 months;", St. Petersburg, Flroida, May, 1972.

[14]Extrapolated from the "ANNUAL FINANCIAL REPORT FOR SCHOOL YEAR beginning JULY 1, 1971, and ending JUNE 30, 1972, SCHOOL BOARD OF DADE COUNTY, FLORIDA", by the School Plant Management Section, Bureau of School Facilities, Division of Elementary Secondary Education, Department of Education, State of Florida.

TABLE FIVE

TABULATION OF AVERAGE COSTS PER YEAR FOR OWNING AND OPERATING

FUNDS	TEST YEAR * CURRENT		Diff	BONDS		Diff
SCHOOL	Eisenhower	Bel-Aire		Eisenhower	Bel-Aire	
TOTAL	$15,068.82	$19,723.99	31%	$17,868.23	$25,808.85	44%
PER COMPRESSOR TON	$ 112.45	$ 160.62	43%	$ 133.34	$ 210.17	58%
PER SQ. FT. CONDITIONED SPACE	$ 0.3667	$ 0.5629	54%	$ 0.4348	$ 0.6281	45%
PER STUDENT HOUR OF ATTENDANCE	$ 0.0260	$ 0.0369	42%	$ 0.0308	$ 0.0483	57%

Formula for cost per student hour of attendance

Eisenhower: On double session

$$\frac{\text{Average Cost of Owning \& Operating Per Year}}{180 \text{ days} \times [(400 \text{ Pupils} \times 5 \text{ hrs}) + (243 \text{ pupils} \times 5 \text{ hrs})]} = \text{Cost Per Student Hour of Attendance}$$

TABLE SIX

COST FOR OWNING AND OPERATING SCHOOL YEAR SEPTEMBER 1, 1971 TO JUNE 1, 1972

SCHOOL NAME		EISENHOWER		BEL-AIRE	
CAPITAL IMPROVEMENT FUND SOURCE		CURRENT EXPENSES	BONDS	CURRENT EXPENSES	BONDS
Amortization, Roof Top Multi-zone Units	$42,500.00* 10 year longevity	$ 4,250.00	$ 4,250.00		
Ductwork, Etc., and Metal Ductwork Equivalent Amount	$46,370.00* 20 year longevity	$ 2,318.50	$ 2,318.50		
Electric Cost		$ 7,222.84	$ 7,222.84		
Maintenance Cost, Air-Conditioning		$ 1,277.48	$ 1,277.48		
Money Cost, Roof Top Multi-zone Units	$42,500 x (20 + 1) x .06 20 year maturity 2		$ 1,338.75		
Remainder	$46,370 x (20 + 1) x .06 20 year maturity 2		$ 1,460.66		
Amortization, Air-Conditioning System	$176,500.00* 20 year longevity			$ 8,825.00	$ 8,825.00
Mechanical Equipment Rooms	$16,670.00* 40 year longevity			$ 416.75	$ 416.75
Electrical Cost, Air-Conditioning				$ 7,820.43	$ 7,820.43
Reheat				$ 1,955.12	$ 1,955.12
Maintenance Cost, Air-Conditioning				$ 489.98	$ 489.98
Mechanical Equipment Rooms				$ 216.71	$ 216.71
Money Cost, Air-Conditioning System	$176,500 x (20 + 1) x .06 20 year maturity 2				$ 5,559.74
Mechanical Equipment Rooms	$16,670 x (20 + 1) x .06 20 year maturity 2				$ 525.11
TOTALS		$15,068.82	$17,868.23	$19,723.99	$25,808.85

*See Table One, page x

9 MONTH SCHOOL YEAR **					
CURRENT		Diff	BONDS		Diff
Eisenhower	Bel-Aire		Eisenhower	Bel-Aire	
$19,880.84	$23,518.01	18%	$24,845.87	$29,602.87	19%
$ 148.36	$ 191.52	29%	$ 185.42	$ 241.07	30%
$ 0.4838	$ 0.6712	39%	$ 0.6046	$ 0.8449	40%
$ 0.0343	$ 0.0440	28%	$ 0.0427	$ 0.0554	29%

12 MONTH SCHOOL YEAR ***					
CURRENT		Diff	BONDS		Diff
Eisenhower	Bel-Aire		Eisenhower	Bel-Aire	
$24,253.84	$28,996.00	20%	$29,218.87	$35,080.86	20%
$ 181.00	$ 236.12	31%	$ 218.05	$ 285.68	31%
$ 0.5902	$ 0.8276	40%	$ 0.7110	$ 1.0013	41%
$ 0.0419	$ 0.0543	30%	$ 0.0504	$ 0.0657	30%

Bel-Aire: $\frac{\text{Average Cost of Owning \& Operating Per Year}}{\text{180 days x 494 pupils x 6 hours}}$ = Cost Per Student Hour of Attendance

* From Table Six, page 12
** From Table Seven, page 13
*** From Table Eight, page 14

TABLE SEVEN

AVERAGE COST PER YEAR FOR OWNING AND OPERATING 9 MONTH SCHOOL YEAR – 20 YEAR CYCLE

SCHOOL NAME		EISENHOWER		BEL-AIRE	
CAPITAL IMPROVEMENT FUND SOURCE		CURRENT EXPENSES	BONDS	CURRENT EXPENSES	BONDS
Amortization,					
Air-Conditioning System	$ 88,870.00*				
Replacement Roof Top Units	68,750.00**				
	$157,620.00				
	Average $157,620.00 / 20 year longevity	$ 7,881.00	$ 7,881.00		
Electric Cost		$ 7,222.84	$ 7,222.84		
Maintenance Cost,					
Air-Conditioning		$ 4,777.00	$ 4,777.00		
Money Cost	$157,620 x (20 + 1) x .06 / 20 year maturity 2		$ 4,965.03		
*See Table One, page 8					
**See page 7					
Amortization,					
Air-Conditioning System	$176,500.00* / 20 year longevity			$ 8,825.00	$ 8,825.00
Mechanical Equipment Rooms	$16,670.00* / 40 year longevity			$ 416.75	$ 416.75
Electric Cost,					
Air-Conditioning				$ 7,820.43	$ 7,820.43
Reheat				$ 1,955.12	$ 1,955.12
Maintenance Cost,					
Air-Conditioning				$ 4,284.00	$ 4,284.00
Mechanical Equipment Rooms				$ 216.71	$ 216.71
Money Cost,					
Air-Conditioning System	$176,500 x (20 + 1) x .06 / 20 year maturity 2				$ 5,559.75
Mechanical Equipment Rooms	$ 16,670 x (20 + 1) x .06 / 20 year maturity 2				$ 525.46
*See Table One, page 8					
TOTALS		$19,880.84	$24,845.87	$23,518.01	$29,602.87

TABLE EIGHT

AVERAGE COST PER YEAR FOR OWNING AND OPERATING
12 MONTH SCHOOL YEAR – 20 YEAR CYCLE

SCHOOL NAME			EISENHOWER		BEL-AIRE	
CAPITAL IMPROVEMENT FUND SOURCE			CURRENT EXPENSES	BONDS	CURRENT EXPENSES	BONDS
Amortization,						
Air Conditioning System	$ 88,870.00*					
Replacement Roof Top Units	$ 68,750.00**					
	$157,620.00					
		Average $157,620.00 / 20 year longevity	$ 7,881.00	$ 7,881.00		
Electric Cost,						
9 Month School Year			$ 7,222.84	$ 7,222.84		
Estimate for 3 months			$ 2,550.00	$ 2,550.00		
Maintenance Cost,						
Air Conditioning			$ 6,600.00	$ 6,600.00		
Money Cost		$157,620 x (20 + 1) / 20 year maturity x .06 / 2		$ 4,965.03		
* See Table One, Page 8						
** See page 7						
Amortization,						
Air Conditioning System		$176,500.00* / 20 year longevity			$ 8,825.00	$ 8,825.00
Mechanical Equipment Rooms		$16,670.00* / 40 year longevity			$ 416.75	$ 416.75
Electric Cost,						
Air Conditioning					$ 7,820.41	$ 7,820.41
Estimate for 3 months					$ 3,000.00	$ 3,000.00
Reheat,					$ 2,705.00	$ 2,705.11
Maintenance Cost,						
Air Conditioning					$ 6,012.00	$ 6,012.00
Mechanical Equipment Rooms					$ 216.71	$ 216.71
Money Cost,						
Air Conditioning System		$176,500 x (20 + 1) / 20 year maturity x .06 / 2				$ 5,559.75
Mechanical Equipment Rooms		$16,670 x (20 + 1) / 20 year maturity x .06 / 2				$ 525.11
* See Table One, Page 8						
		TOTALS	$24,251.84	$29,218.87	$28,996.00	$35,080.86

CONCLUSIONS

Every attempt has been made to eliminate, or neutralize, all known or assumed inequities that might tend to invalidate the findings of this study. Conversely, every attempt was made to select subjects for comparison that were devoid of these inequities. Finally, similar or identical procedures as appropriate were utilized for metering and collecting data that would yield, by very careful analysis, results that could be completely substantiated and defended.

These results have shown conclusively that it is more economical to own and operate the roof-mounted, multi-zoned unitary type air-conditioning system at the Eisenhower Elementary School in Palm Beach County than to own and operate the central chilled water, terminal heat/reheat, type air-conditioning system at the Bel-Aire Elementary School in Dade County. The evidence indicates this to also be true regardless of the method of funding.

Purchasers of the air-conditioning systems for Florida schools are encouraged to consider the cost findings of this study along with the educational requirements, use, housing needs, location, size, funding capabilities, economic conditions, weather, and other factors.

APPENDIX

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TABLE NINE

EXAMPLE OF MONTHLY POWER COST CALCULATION · BEL-AIRE SCHOOL
April 3, 1972 to May 3, 1972

KILOWATT DEMAND

Actual Maximum Kilowatt Demand		=	317 KWD
Amount Kilowatt Demand Billed	317 – 20	=	297 KWD
Air-Conditioning Kilowatt Demand	51 KW Peak x 3.6 *	=	183.6 KWD
Heat/Reheat Kilowatt Demand	0.355 KW Peak x 120*	=	42.6 KWD
Building Kilowatt Demand	317–(183.6 + 42.6)	=	90.8 KWD

KILOWATT HOURS USED

Total, Billed		=	99,000 KWH
Air-Conditioning			
A/C Watt Hr. Meter Reading	3199 Off – 2306 on	=	893 WH
	893 Watt Hours x 60 *	=	53,580 KWH
Heat/Reheat			
H/RH Watt Hr. Meter Reading	[½ x (0273 Off – 0000 on)]	=	136.5 WH
	136.5 Watt Hours x 120*	=	16,380 KWH
Building	99,000 – (53,580 + 16,380)	=	29,040 KWH

COSTS

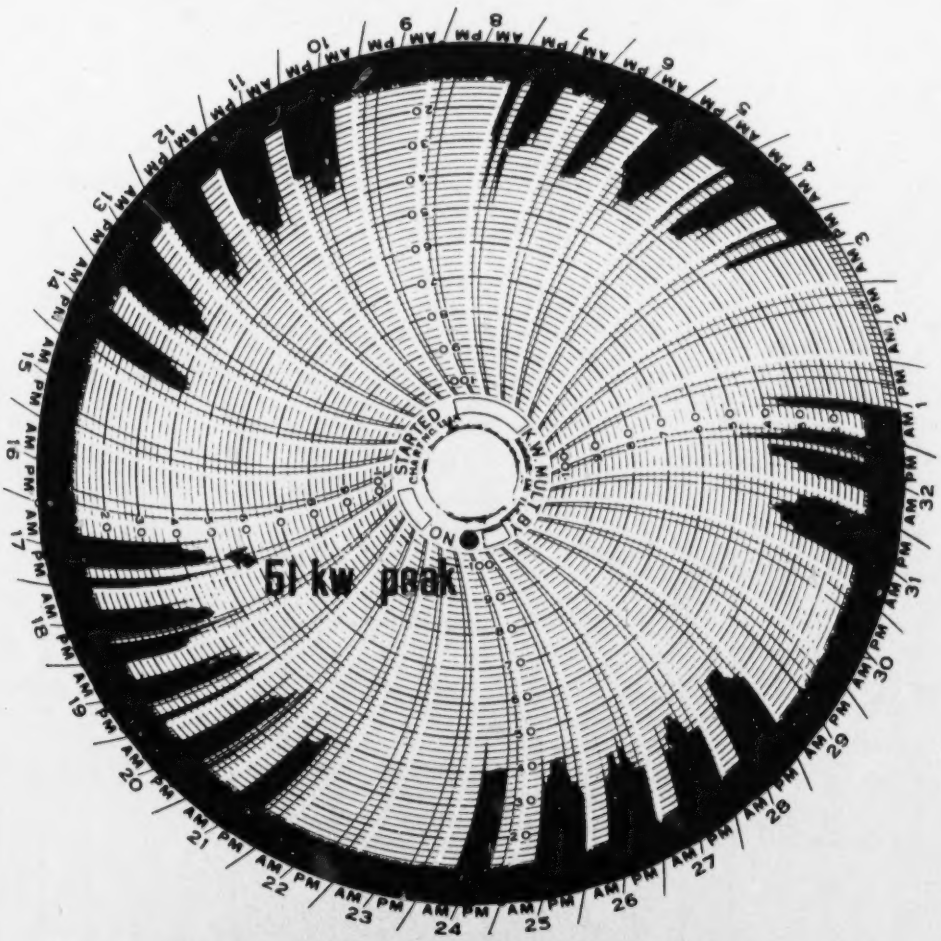
Air-Conditioning Demand			
297 / 317 x 183.6 x	$ 1.75	= $	301.03
Air-Conditioning Kilowatt Hours			
53,580 / 99,000 x	($ 1797.51 – $ 519.75)	=	691.54
Credits			
53,580 / 99,000 x	($ 339.50 + $100.00)	=	–237.86
Adjustments			
183.6 / 317 x	$ 142.56	=	82.57
			$ 837.28
Heat/Reheat Demand			
297 / 317 x 42.6 x	$ 1.75	= $	69.85
Heat/Reheat Kilowatt Hours			
16,380 / 99,000 x	($ 1797.51 – $ 519.75)	=	211.41
Credits			
16,380 / 99,000 x	($ 339.50 + $ 100.00)	=	– 72.72
Adjustments			
42.6 / 317 x	$ 142.56	=	19.16
			$ 227.70 **
Building Demand			
297 / 317 x 90.8 x	$ 1.75	= $	148.87
Building Kilowatt Hours			
29,040 / 99,000 x	($ 1797.51 – $ 519.75)	=	374.81
Credits			
29,040 / 99,000 x	($ 339.50 + $ 100.00)	=	– 128.92
Adjustments			
90.8 / 317 x	$ 142.56	=	40.83
			$ 435.59

ELECTRIC POWER COMPANY BILL 5-3-71, TOTAL		$ 1500.57
Heat/Reheat Power Cost	= $ 227.70	
Air-Conditioning Power Cost	= $ 837.28	
TOTAL HVAC POWER COST (ACTUAL)		$ 1064.98
Heat/Reheat Power Cost (25% of A/C Power Cost)	= $ 209.32	
Air-Conditioning Power Cost	= $ 837.28	
TOTAL HVAC POWER COST (CALCULATED)		$ 1046.60

*Meter Constant
**Heat/Reheat is 27% ($227.70/$837.28 = 0.2719) of the air-conditioning power cost.

CHART ONE

EXAMPLE OF KILOWATT GRAPHIC RECORDING



10-251.1 SCHOOL	6	SD 952-550
10202 SW 196 ST		A-C
7V32014	12W-2719	G-9
60	9.	3.6

WATTHOUR METER READING	3195	DEMAND METER KWH RDG.	79666
SET		REMOVED	
TIME	2.44 AM PM	TIME	10.50 AM PM
DATE	4-3 1972	DATE	5-3 1972
BY		BY	

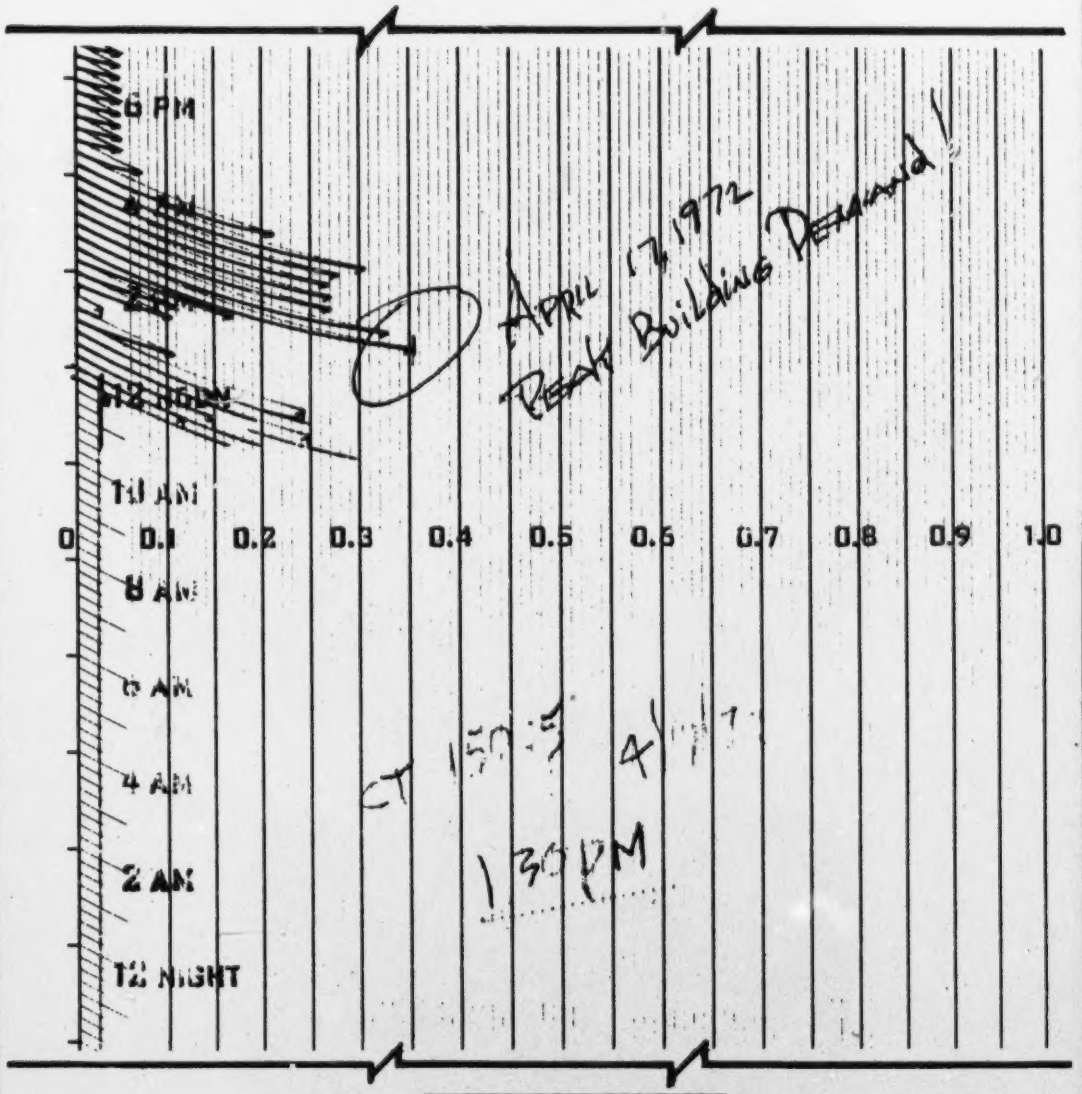
FORM 500 3/59 GRAPHIC CHART LABEL

BEL-AIRE SCHOOL

APRIL 3,1972 TO MAY 3,1972 FOR AIR-CONDITIONING POWER USED

CHART TWO

EXAMPLE OF KILOWATT GRAPHIC RECORDING CHART



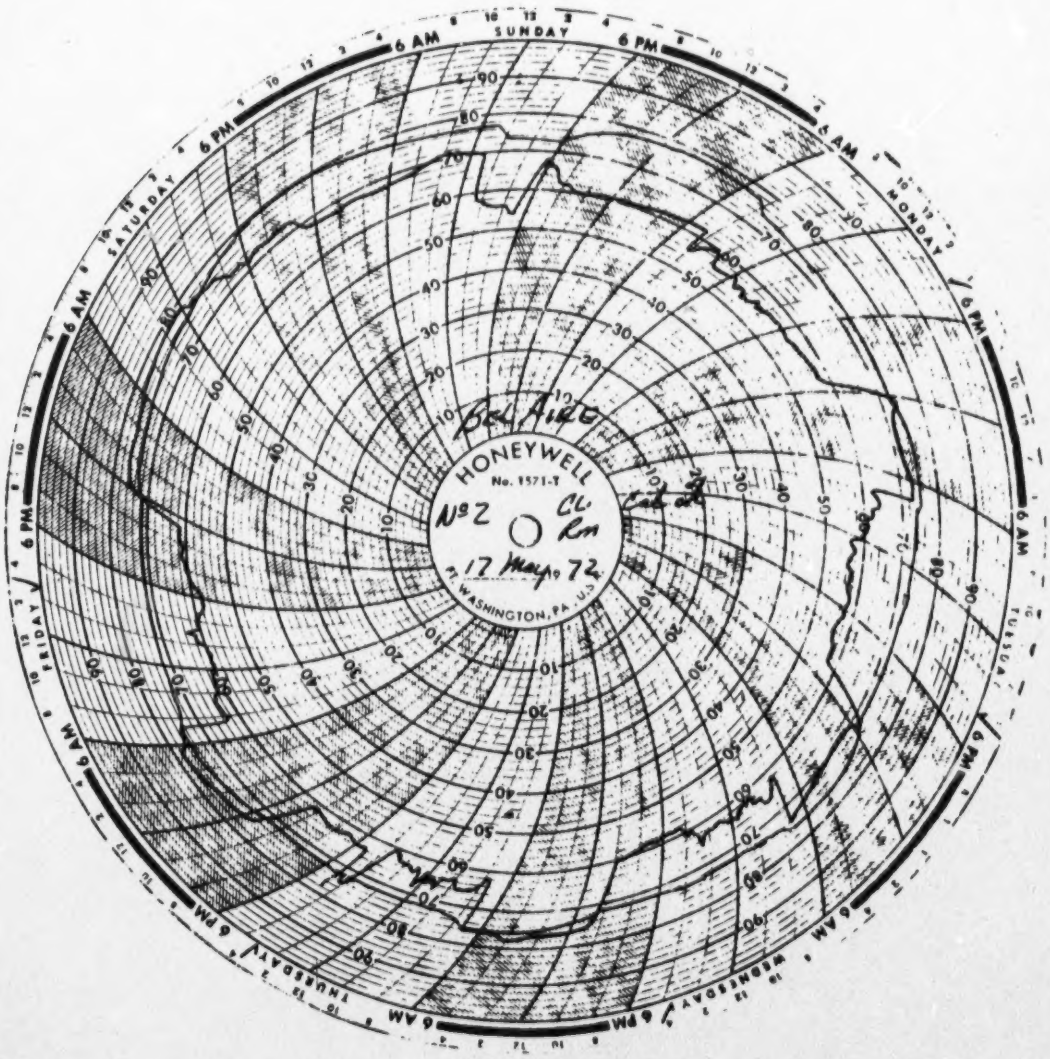
*METER CONSTANT=120

BEL-AIRE SCHOOL

APRIL 3,1972 TO MAY 3,1972 FOR HEAT/REHEAT POWER USED

CHART THREE

EXAMPLE OF TEMPERATURE & HUMIDITY GRAPHIC RECORDING CHART



BEL-AIRE SCHOOL

TABLE TEN

TABULATION OF MAINTENANCE COSTS FOR AIR-CONDITIONING AT BEL-AIRE SCHOOL SEPTEMBER 1, 1971 TO JUNE 1, 1972

9/3/71	Checked and adjusted thermostats	
	4 hrs. labor @ $6.23 an hour	$ 24.92
	Vehicle charge	4.45
		$ 29.37
10/5/71	Cleaned dirty filters	
	3 hrs. labor @ $6.23 an hour	$ 18.69
	Vehicle charge	4.45
		$ 23.14
11/23/71	Preventative Maintenance	
	4.5 hrs. labor @ $6.23 an hour	$ 28.04
	Materials	1.02
	Vehicle charge	4.45
		$ 33.51
12/1/71	Preventative Maintenance	
	1 hr. labor @ $6.23 an hour	$ 6.23
	Materials	4.00
	Vehicle charge	4.45
		$ 14.68
2/28/72	Chiller - 2, did not come on	
	6 hrs. labor @ $6.23 an hour	$ 37.38
	Materials	20.08
	Vehicle charge	4.45
		$ 61.91
3/21/72	Checked heating-too much-replaced filters	
	12 hrs. labor @ $6.23 an hour	$ 74.76
	Materials	168.60
	Vehicle charge	4.45
		$247.81
5/9/72	Recalibrated thermostat-too hot	
	1.5 hrs. labor @ $6.23 an hour	$ 9.35
	Materials	5.24
	Vehicle charge	4.45
		$ 19.04
5/23/72	Pod 300 & 400 not cool	
	9 hrs. labor @ $6.23 an hour	$ 56.07
	Materials	-
	Vehicle charge	4.45
		$ 60.52

Total of all above. . . . $ 489.98

TABLE ELEVEN

TABULATION OF MAINTENANCE COSTS FOR AIR-CONDITIONING AT EISENHOWER SCHOOL SEPTEMBER 1, 1971 TO JUNE 1, 1972

9/1/71	PO #54197 - ACR				
	Labor:	2 Mechanics - 16 hrs.	@ $6.41 =	$ 205.12	
		1 Helper - 16 hrs.	@ $2.83 =	$ 45.28	$ 250.40
	Parts:	10 - FRM 35 Fusetrons			9.00
		6 - Schaffer Roller Bearings 1 3/16			175.80
	Mileage:	24 miles @ 15¢ per mile			3.60
9/10/71	PO #54312 - Electromatic Equipment Company				
	Labor:	1 Mechanic - 8 hrs.	@ $6.41 =	$ 51.28	
		1 Helper - 8 hrs.	@ $2.83 =	$ 22.64	$ 73.92
	Parts:	Compressor Discharge Valve Plates			
		Unloader mechanism solenoid coil for Unloader Unit D.			149.92
		Freon 22 - 25 lbs. @ 97¢ per lb.			24.25
	Mileage:	24 miles @ 15¢ per mile			3.60
9/13/71	Greased bearings on all units, replaced belts on two units.				
	Labor:	1 Mechanic - 6 hrs.	@ $6.41 =	$ 38.56	
		1 Helper - 6 hrs.	@ $2.83 =	$ 16.98	$ 55.44
	Parts:	5 - Belts @ $2.51 per belt			12.55
	Mileage:	24 miles @ 15¢ per mile			3.60
9/14/71	Replaced thermostat for Unit D.				
	Labor:	1 Mechanic - 1½ hrs.	@ $6.41 =	$ 9.61	
		1 Helper - 1½ hrs.	@ $2.83 =	$ 4.24	$ 13.85
	Parts:	Thermostat			31.50
	Mileage:	24 miles @ 15¢ per mile			3.60
10/16/71	Greased bearings and checked all belts.				
	Labor:	1 Mechanic - 4 hrs.	@ $6.41 =	$ 25.64	
		1 Helper - 4 hrs.	@ $2.83 =	$ 11.32	$ 36.96
	Mileage:	24 miles @ 15¢ per mile			3.60
11/17/71	Greased bearings and checked all belts.				
	Labor:	1 Mechanic - 4 hrs.	@ $6.41 =	$ 25.64	
		1 Helper - 4 hrs.	@ $2.83 =	$ 11.32	$ 36.96
	Mileage:	24 miles @ 15¢ per mile			3.60
12/10/71	Greased bearings and checked all belts.				
	Labor:	1 Mechanic - 4 hrs.	@ $6.41 =	$ 25.64	
		1 Helper - 4 hrs.	@ $2.83 =	$ 11.32	$ 36.96
	Mileage:	24 miles @ 15¢ per mile			3.60
1/10/72	Greased bearings and checked all belts.				
	Labor:	1 Mechanic - 4 hrs.	@ $6.41 =	$ 25.64	
		1 Helper - 4 hrs.	@ $2.83 =	$ 11.32	$ 36.96
	Mileage:	24 miles @ 15¢ per mile			3.60
2/14/72	Greased bearings and checked all belts.				
	Labor:	1 Mechanic - 4 hrs.	@ $6.41 =	$ 25.64	
		1 Helper - 4 hrs.	@ $2.83 =	$ 11.32	$ 36.96
	Mileage:	24 miles @ 15¢ per mile			3.60
3/8/72	Greased bearings and replaced belts				
	Labor:	1 Mechanic - 8 hrs.	@ $6.41 =	$ 51.28	
		1 Helper - 8 hrs.	@ $2.83 =	$ 22.64	$ 73.92
	Mileage:	24 miles @ 15¢ per mile			3.60
	Materials:	PO #57921 Butler Refrigeration			
		2 4L520 belts		$ 3.52	
		2 E60 heaters		$ 2.88	
		2 E61 heaters		$ 2.88	$ 9.28
5/15/72	Repaired leak in Unit D4 on evaporator and added freon. Replaced heater relay.				
	Labor:	1 Mechanic - 8 hrs.	@ $6.41 =	$ 51.28	
		1 Helper - 8 hrs.	@ $2.83 =	$ 22.64	$ 73.92
	Mileage:	30 miles @ 15¢ per mile			4.50
	Materials:	50 lbs. freon		$ 48.50	
		Relay		$ 4.95	$ 53.45
5/16/72	Replaced heaters in evaporator motor starter.				
	Labor:	1 Mechanic - 4 hrs.	@ $6.41 =	$ 25.64	
		1 Helper - 4 hrs.	@ $2.83 =	$ 11.32	$ 36.96
	Mileage:	30 miles @ 15¢ per mile			$ 4.50
	Materials:	PO-# 57921 Butler Refrigeration			
		2 #4L520 belts		$ 3.52	

Total of all above. . . . $ 1,277.48